# KANSAS GEOLOGICAL SURVEY
# OPEN-FILE REPORT 95-45d

## INITIAL MONITORING RESULTS AND INSTALLATION DETAILS FROM THE WITT INTENSIVE STUDY SITE ON RATTLESNAKE CREEK, STAFFORD COUNTY, KANSAS

by

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**Initial Monitoring Results and Installation Details from the Witt Intensive Study Site on Rattlesnake Creek, Stafford County, Kansas**

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A cooperative investigation by

The Kansas Geological Survey and
Big Bend Groundwater Management District No. 5

As part of the Mineral Intrusion Project, an intensive study site was established adjacent to Rattlesnake Creek (RSC) in cooperation with landowners Norman and Theodore (Pete) Witt. The site is located in Stafford County approximately 1 mile south of Hudson, Kansas, at the following legal location: NE/4 NE/4 NE/4 Sec. 5 T23S-R12W. See figure 1 for the location of the Witt site in relation to other monitoring well sites and physical features. A detailed description of the installation and development of the monitoring wells and stream gage is provided in Appendix A.

The primary objective was to establish a monitoring and logging well site to permit observation of possible saltwater discharge gradients and bedrock-stream hydraulic gradients in relation to stream flow. Secondary objectives included water sampling for determination of salinity and saltwater source, and collection of Permian core for permeability and porosity testing.

The Witt site consists of three shallow observation wells (or piezometers), one well screened in the Permian bedrock, and a stream gage. The wells are oriented perpendicular to Rattlesnake Creek (see figures 2 and 3 and table 1 for site layout and well characteristics). The shallow wells are used to monitor water-level changes and water chemistry in the upper unconsolidated sediments at increasing distances from Rattlesnake Creek. The Permian well is used primarily to track the hydraulic head in the Permian bedrock and to monitor the elevation of the freshwater-saltwater interface in the Great Bend Prairie aquifer using focused EM induction logging.

The site is situated in a location where a clear definition of the unconsolidated stratigraphic sequence is important. In general, the stratigraphy consists of 147 feet of an interbedded sequence of unconsolidated sand, gravel, silt, and clay of Quaternary age overlying an alternating sequence of siltstone, sandstone, and shale of Permian age. Knowledge of the distribution of clay layers is important because these low-permeable units can control the vertical movement of saltwater. Analysis of detailed drilling and geophysical logs shows that clay layers or lenses can be distinguished from more permeable sands and gravels. See table 2 for lithologic log and figure 4 for natural gamma and EM induction (formation conductivity) logs from the Witt Permian well.

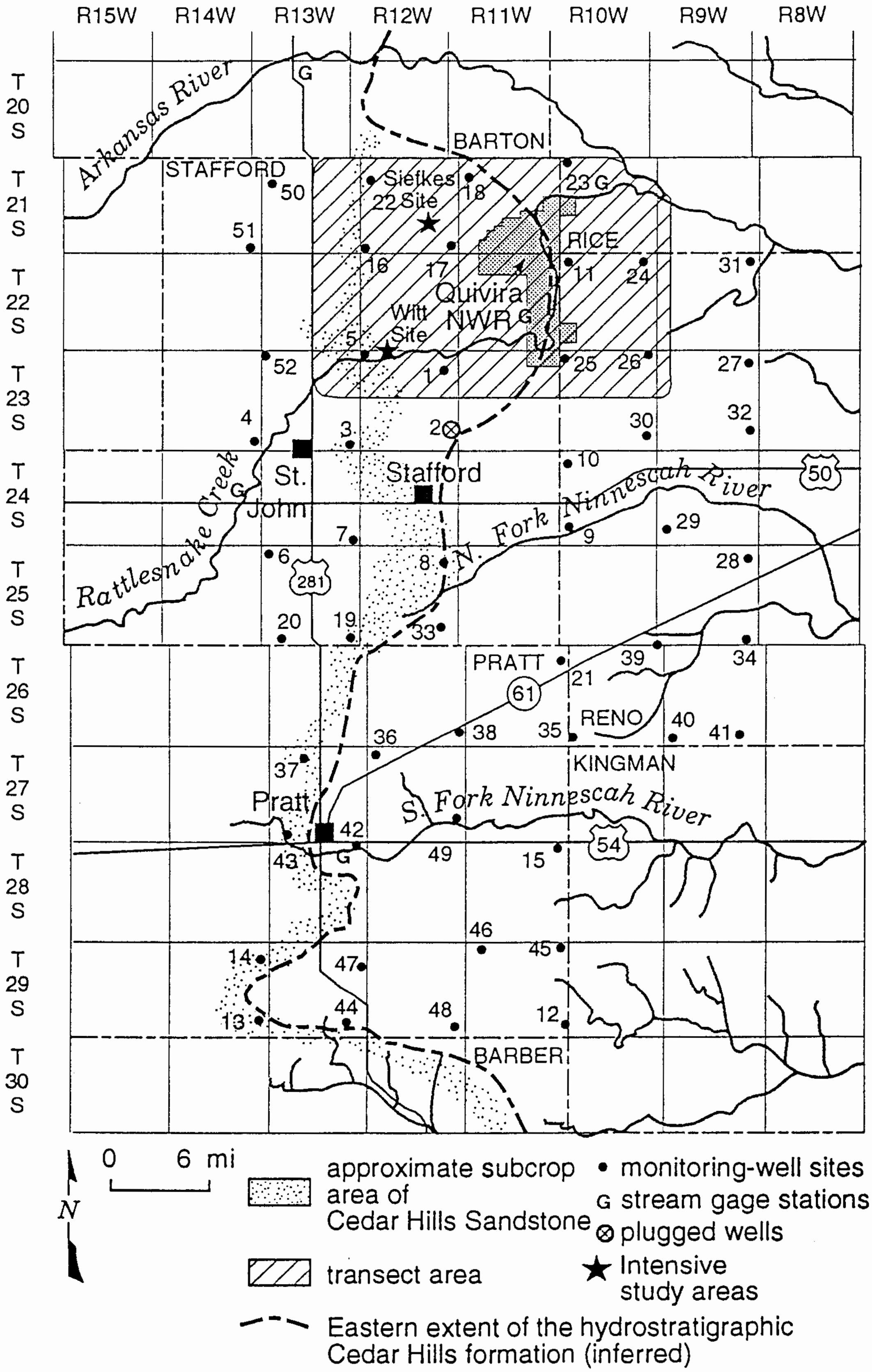


Figure 1. Observation wells and other physical features in the area of the KGS/GMD5 monitoring-well network.

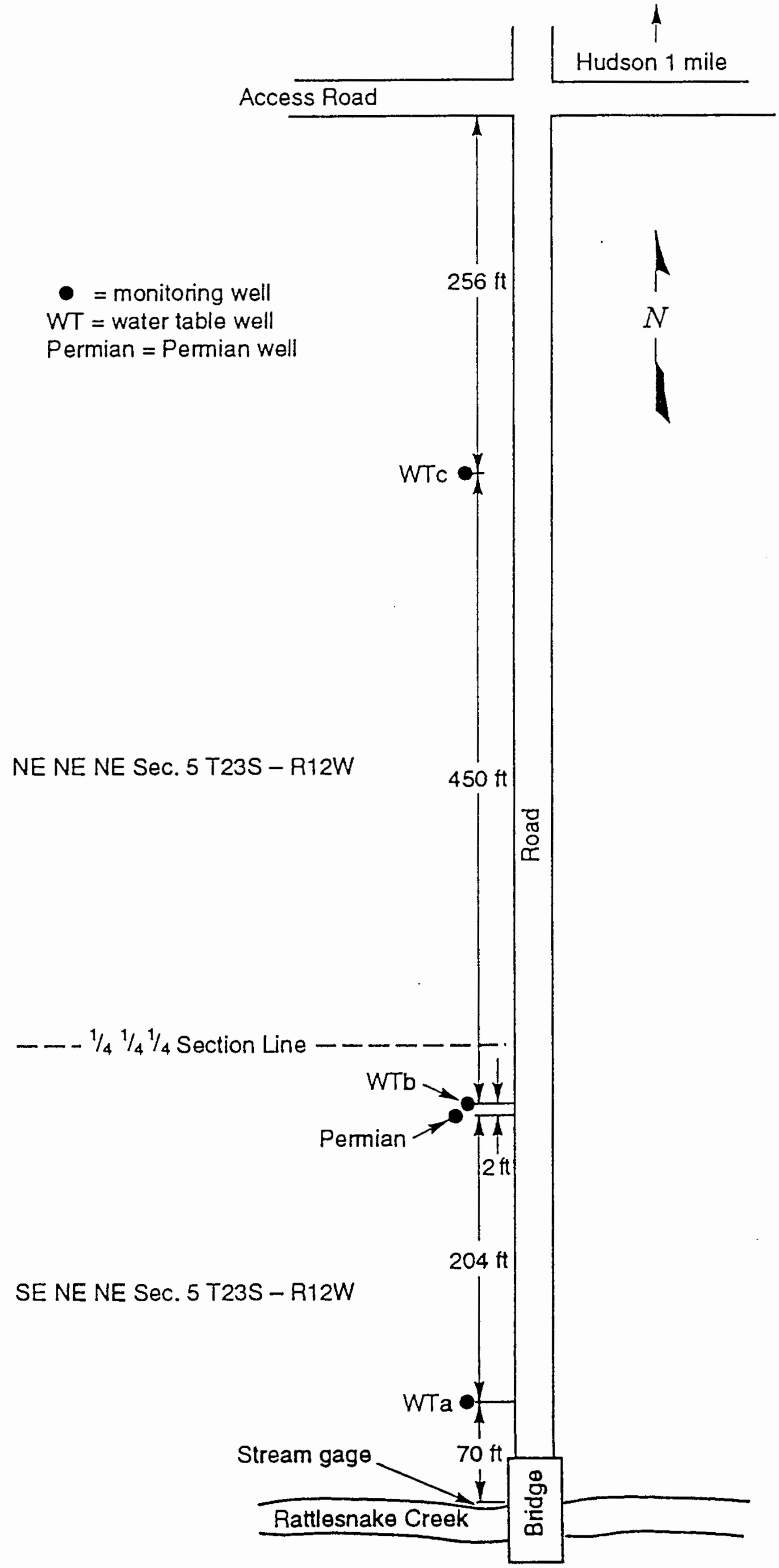


Figure 2. Plan of Witt Intensive Study Site.

Table 1. Information for wells at the Witt Intensive Study Site.

| ID | Location | Elev. (ft) | Depth (ft) | Screen (ft) |
|---|---|---|---|---|
| WTa | NE SE NE NE Sec 5 T23-R12 | 1841.1 | 37 | 32 – 37 |
| WTb | NE SE NE NE Sec 5 T23-R12 | 1843.7 | 38 | 33 – 38 |
| WTc | NE NE NE NE Sec 5 T23-R12 | 1842.2 | 36.5 | 31.5 – 36.5 |
| Permian | NE SE NE NE Sec 5 T23-R12 | 1843.7 | 179 | 159 – 179 |

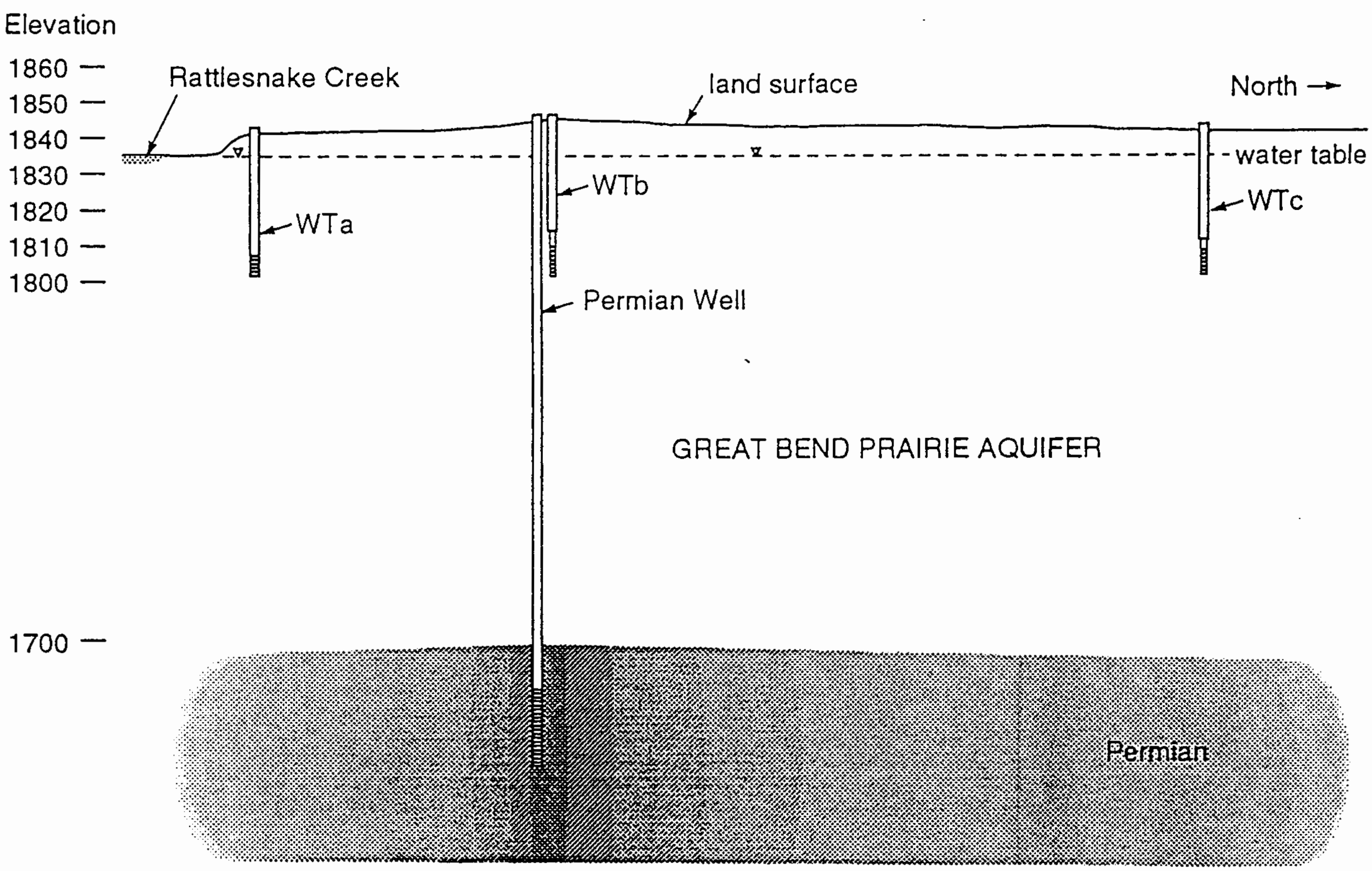


Figure 3. Cross section of Witt Intensive Study Site. Vertical exaggeration: 2.5x.

Table 2. Lithologic log from Witt site Permian well.

LOCATION: NE NE Sec. 5 T23S R12W　　　　　　　　　COUNTY: STAFFORD

WELL LOG

| FROM | TO | LITHOLOGIC LOG |
|---|---|---|
| 0 | 5 | topsoil, brown sandy clay |
| 5 | 10 | same, more clayey |
| 10 | 20 | dark brownish gray silt, some sandy clay |
| 20 | 25 | silty clay, some sand |
| 25 | 26 | heavy black clay stringer |
| 26 | 35 | fine to mediun sand, poorly sorted, arkosic |
| 35 | 40 | same, not as coarse |
| 40 | 45 | same |
| 45 | 50 | same, coarser, plus minor caliche |
| 50 | 60 | sand and silt |
| 60 | 70 | silt with some fine sand; white/tan clay stringers |
| 70 | 75 | silt with fine sand |
| 75 | 78 | red sand and gravel |
| 78 | 80 | lt. brown clay |
| 80 | 90 | red sand and gravel, some lt. brown clay stringers |
| 90 | 100 | same, harder clay |
| 100 | 110 | sand and gravel, yellow clay stringers |
| 110 | 115 | less sand and gravel, more clay at 112-115 ft. |
| 115 | 120 | more sand |
| 120 | 125 | yellowish brown clay, some red siltstone (Dakota?) |
| 125 | 130 | same, more red siltstone |
| 130 | 138 | mostly sand, some clay; less clay with depth (reworked Dakota?) |
| 138 | 144 | coarse sand |
| 144 | 145 | yellow clay |
| 145 | 147 | lt. gray siltstone |
| 147 | 159 | red siltstone--Permian |
| 159 | 160 | lt. reddish brown siltstone |
| 160 | 161 | lt. red siltstone |
| 161 | 162.5 | red very fine sandstone with yellowish interbedding, many black specks (organic fragments?) |
| 162.5 | 163 | lt. yellowish brown very fine sandstone |
| 163 | 163.5 | lt. gray siltstone, friable |
| 163.5 | 163.8 | red siltstone |
| 163.8 | 164 | lt. gray siltstone |
| 164 | 165 | red siltstone, few lt. gray mottles |
| 165 | 166 | red muddy siltstone, few lt. gray streaks and mottles |
| 166 | 176 | red siltstone, few lt. gray mottles, more mottles with depth |
| 176 | 176.5 | same, bedding surface at 176 ft. |
| 176.5 | 177 | red very fine sandstone, lt. gray mottles, many large vugs (up to 3/8 in.), few anhydrite nodules |
| 177 | 178 | red very fine sandstone, few vugs |
| 178 | 179 | red siltstone, large vugs at 178.5 ft. |

Witt Site Permian Well

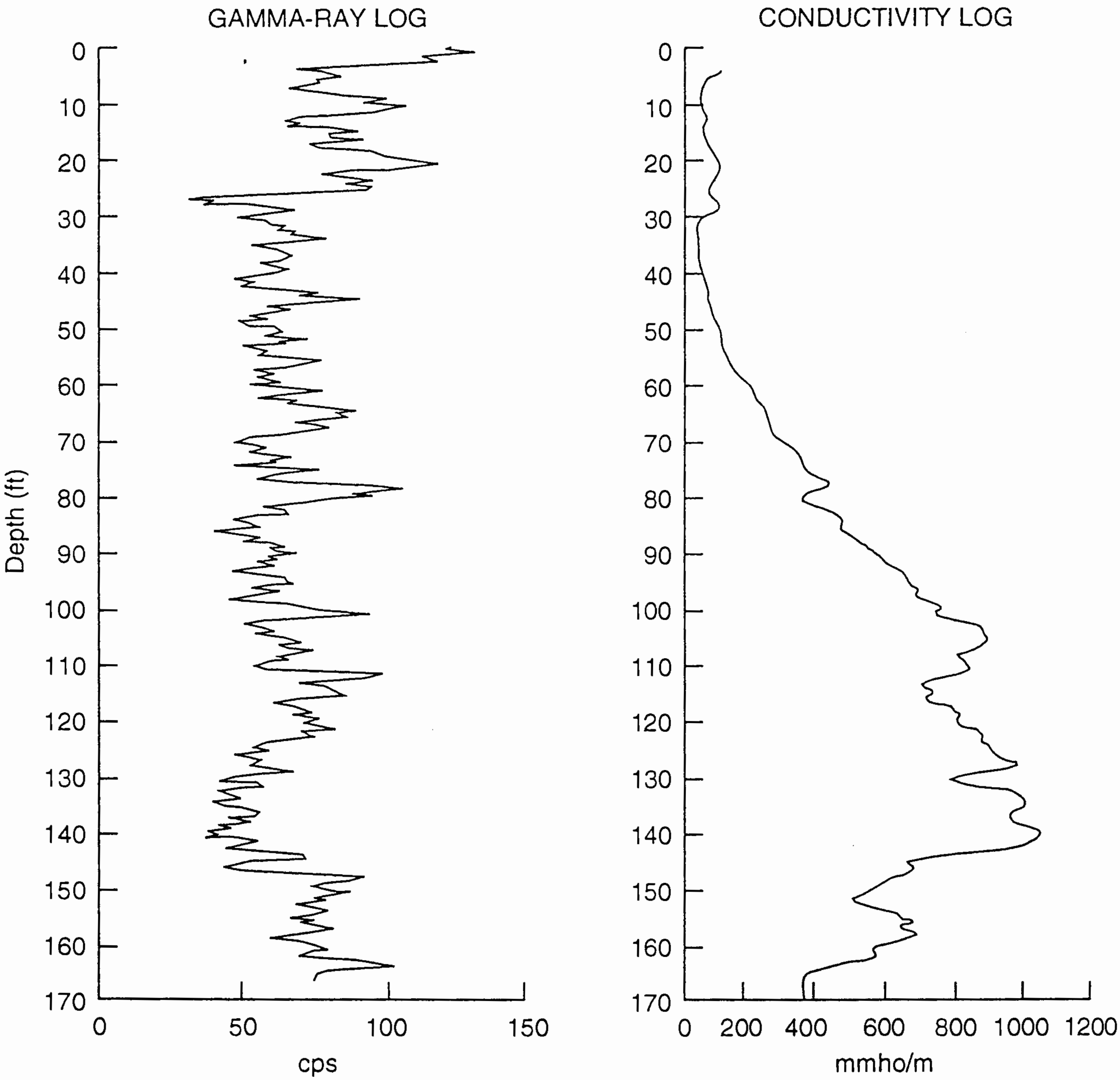


Figure 4. Geophysical logs from the Witt site Permian well.

Water Levels

A limited amount of data has been collected at the Witt site, however some preliminary interpretations can be made based on the observations. Water level information is listed in table 3 and illustrated in figure 5. Water levels are higher at increasing distances from the creek, indicating that Rattlesnake Creek is a gaining stream receiving natural groundwater discharge. Water level rises and declines are observed at the same time in water table wells and in Rattlesnake creek, however larger fluctuations are observed in the creek. Fluctuations in the Permian well are similar but slightly more subdued.

The stream level remained fairly steady overwinter, with a net rise of only 0.2 ft. Water levels in wells, including the Permian well, rose about 1 foot. Heavy rains in late March and early May resulted in significant water level rises. A net rise of more than 3 ft was observed in all wells (including the Permian well) before receeding in June. Both the stream level and water levels in wells show fairly rapid response to rainfall. The response in the Permian well appears less rapid than in the other wells.

Because of the episodic storms in May, Rattlesnake Creek flooded out of its bank at least twice. As a result, the stream gage at the site was inundated at least twice and some data that would help us determine detailed short-term stream-aquifer interactions are not available. On May 23, the flooded surface water was up to the wellhead of WTa (not shown in figure 5), some 5 ft higher than the normal stream level.

At last observation (June 21,1995), the stream level had returned to pre-May levels, but water levels in wells remained some 2 ft higher than pre-May levels. As a result of the Permian head rise in May, the head in the Permian well was within 0.3 ft of the stream level elevation at the time of the last observation.

Water Chemistry and Source of Salinity

The chloride concentrations in the ground waters at the Witt site range from about 200 mg/L in the WTb well to about 40,000 mg/L in the Permian (table 4). The Permian water salinity is the fourth highest observed in the monitoring wells in the Great Bend Prairie area; Permian wells at network sites 5, 6, and 8 yield waters with chloride concentrations of about 41,000, 43,000, and 44,000 mg/L, respectively (Whittemore, 1993). The chemistry of water from the Witt Permian well is very similar to that from the Permian well at site 5 about two miles to the west. The relatively small increase in the salinity of the ground water collected from the Permian well with time is probably related to removal of the last traces of drilling water. The fact that the change is so small indicates that the well was developed sufficiently to yield samples representative of the formation water.

Water from WTa, the water table well closest to Rattlesnake Creek (figure 2) has a chloride concentration of over 800 mg/L at a depth of only 37 ft. Water sampled from

| Table 3A. Witt site water levels. | | | | |
|---|---|---|---|---|
| | | | | |
| | Depth to water (ft) | | | |
| | | | | |
| Date | Permian | WTa | WTb | WTc |
| 9/16/94 | 11.02 | | 6.83 | |
| 10/5/94 | 10.82 | | 6.69 | |
| 10/6/94 | 10.72 | | 6.65 | |
| 10/11/94 | 10.60 | | 6.55 | |
| 10/12/94 | 10.58 | | 6.54 | |
| 10/13/94 | 10.58 | 4.40 | 6.51 | 4.84 |
| 10/27/94 | 10.37 | 4.20 | 6.31 | 4.66 |
| 11/8/94 | 10.25 | 4.01 | 6.19 | 4.54 |
| 11/15/94 | 10.40 | 4.05 | 6.17 | 4.50 |
| 3/9/95 | 9.43 | 3.09 | 5.19 | 3.54 |
| 3/17/95 | 9.39 | 3.05 | 5.04 | 3.43 |
| 4/12/95 | 9.35 | 3.04 | 5.05 | 3.43 |
| 4/13/95 | 9.39 | 3.04 | 5.06 | 3.45 |
| 4/14/95 | 9.35 | 3.02 | 5.03 | 3.40 |
| 4/24/95 | 9.16 | 2.82 | 4.83 | 3.20 |
| 4/28/95 | 9.21 | 2.88 | 4.90 | 3.27 |
| 5/1/95 | 9.05 | 2.63 | 4.65 | 3.02 |
| 5/2/95 | 9.03 | 2.59 | 4.62 | 2.98 |
| 5/3/95 | 8.98 | 2.60 | 4.62 | 2.99 |
| 5/5/95 | 9.01 | 2.66 | 4.69 | 3.06 |
| 5/8/95 | 7.95 | 1.10 | 3.19 | |
| 5/11/95 | | 1.24 | 3.40 | |
| 5/13/95 | 7.78 | 0.94 | 3.00 | |
| 5/15/95 | 7.81 | 1.24 | 3.28 | 1.72 |
| 5/17/95 | 7.50 | 0.76 | 2.84 | 1.25 |
| 5/19/95 | 7.59 | 1.01 | 3.04 | 1.37 |
| 5/23/95 | 6.29 | -0.80 | 1.24 | |
| 5/27/95 | 5.79 | | 1.22 | |
| 6/7/95 | 6.49 | | 2.42 | |
| 6/9/95 | 6.15 | | 1.72 | |
| 6/20/95 | 6.91 | 1.01 | 2.96 | 1.15 |
| 6/21/95 | 6.96 | 1.10 | 3.04 | 1.24 |

| Table 3B. Witt site water levels. | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | Water level elevation (ft above mean sea level) | | | | |
| | | | | | |
| Date | Permian | WTa | WTb | WTc | RSC |
| 9/16/94 | 1832.68 | | 1836.81 | | |
| 10/5/94 | 1832.88 | | 1836.95 | | |
| 10/6/94 | 1832.98 | | 1836.99 | | |
| 10/11/94 | 1833.10 | | 1837.09 | | |
| 10/12/94 | 1833.12 | | 1837.10 | | |
| 10/13/94 | 1833.12 | 1836.71 | 1837.13 | 1837.35 | 1836.32 |
| 10/27/94 | 1833.33 | 1836.91 | 1837.33 | 1837.53 | 1836.40 |
| 11/8/94 | 1833.45 | 1837.10 | 1837.45 | 1837.65 | |
| 11/15/94 | 1833.30 | 1837.06 | 1837.47 | 1837.69 | 1836.40 |
| Date | Permian | WTa | WTb | WTc | RSC |
| 3/9/95 | 1834.27 | 1838.02 | 1838.51 | 1838.65 | 1836.60 |
| 3/17/95 | 1834.31 | 1838.06 | 1838.66 | 1838.76 | 1836.74 |
| 4/12/95 | 1834.35 | 1838.07 | 1838.65 | 1838.76 | 1836.65 |
| 4/13/95 | 1834.31 | 1838.07 | 1838.64 | 1838.74 | 1836.64 |
| 4/14/95 | 1834.35 | 1838.09 | 1838.67 | 1838.79 | 1836.63 |
| 4/24/95 | 1834.54 | 1838.29 | 1838.87 | 1838.99 | 1836.74 |
| 4/28/95 | 1834.49 | 1838.23 | 1838.80 | 1838.92 | 1836.67 |
| 5/1/95 | 1834.65 | 1838.48 | 1839.05 | 1839.17 | 1836.98 |
| 5/2/95 | 1834.67 | 1838.52 | 1839.08 | 1839.21 | 1836.95 |
| 5/3/95 | 1834.72 | 1838.51 | 1839.08 | 1839.20 | 1836.91 |
| 5/5/95 | 1834.69 | 1838.45 | 1839.01 | 1839.13 | 1836.84 |
| 5/8/95 | 1835.75 | 1840.01 | 1840.51 | | 1838.71 |
| 5/11/95 | | 1839.87 | 1840.30 | | |
| 5/13/95 | 1835.92 | 1840.17 | 1840.70 | | |
| 5/15/95 | 1835.89 | 1839.87 | 1840.42 | 1840.47 | 1838.82 |
| 5/17/95 | 1836.20 | 1840.35 | 1840.86 | 1840.94 | 1838.08 |
| 5/19/95 | 1836.11 | 1840.10 | 1840.66 | 1840.82 | 1837.84 |
| 5/23/95 | 1837.41 | 1841.91 | 1842.46 | | |
| 5/27/95 | 1837.91 | | 1842.48 | | |
| 6/7/95 | 1837.21 | | 1841.28 | | |
| 6/9/95 | 1837.55 | | 1841.98 | | |
| 6/20/95 | 1836.79 | 1840.10 | 1840.74 | 1841.04 | 1837.02 |
| 6/21/95 | 1836.74 | 1840.01 | 1840.66 | 1840.95 | 1836.96 |

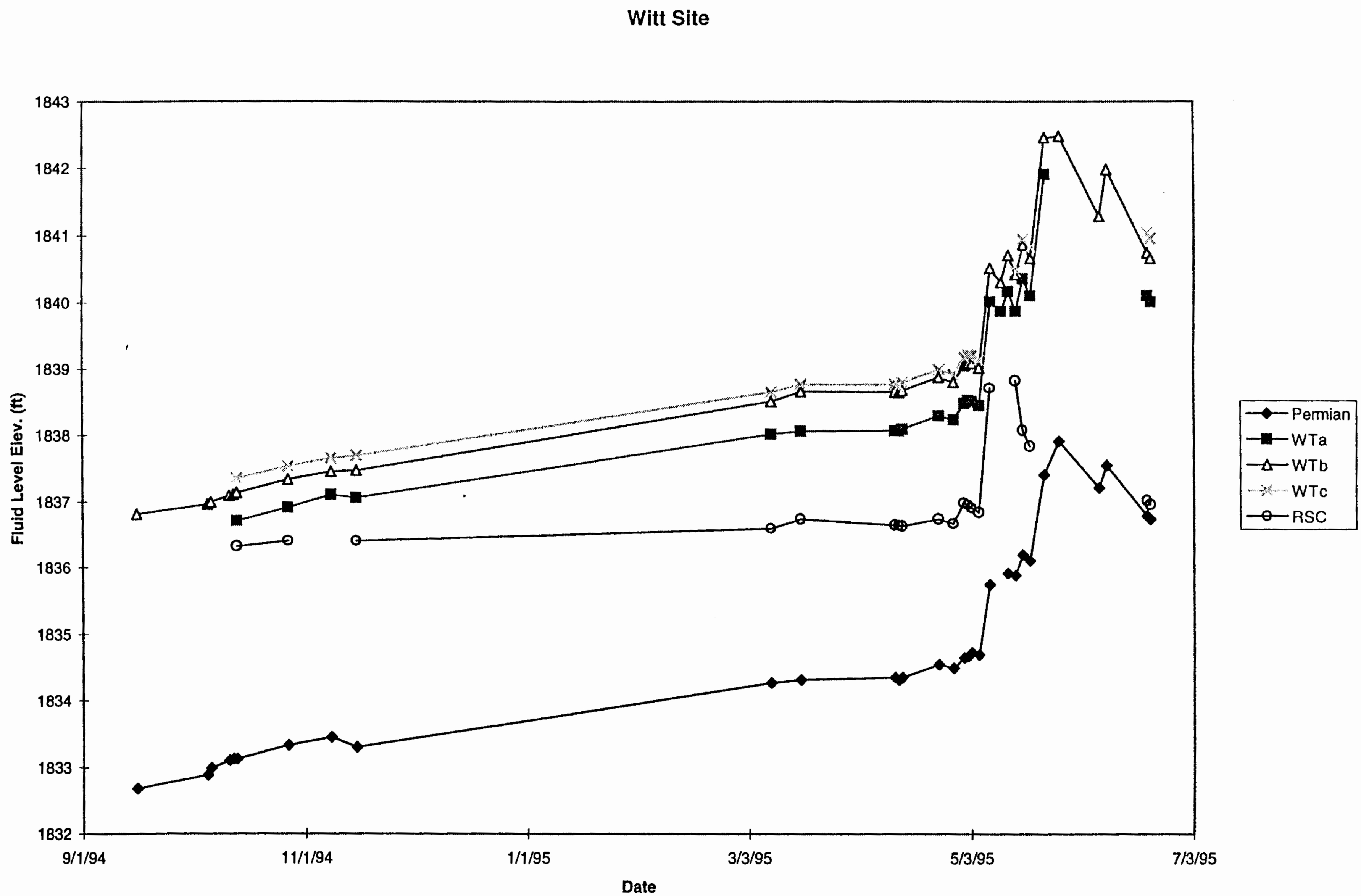


Figure 5. Hydrographs of wells and Rattlesnake Creek (RSC) at the Witt site. Well descriptions and locations are given in table 1 and figures 2 and 3.

Table 4. Chemical data for waters sampled from wells and Rattlesnake Creek at the Witt site.

| Sample site | Date collected | Lab Sp.C. µS/cm | Lab pH | Ca mg/L | Mg mg/L | Na mg/L | K mg/L | Sr mg/L | $HCO_3$ mg/L | Cl mg/L | SO4 mg/L | $NO_3$-N mg/L | $SiO_2$ mg/L | B mg/L | Br mg/L | I mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WTa | 10/12/94 | 2830 | 8.10 | 14.7 | 3.6 | 586 | 2.2 | 0.13 | 250 | 749 | 68.8 | 0.77 | 20.6 | 0.129 | 0.143 | 0.0085 |
| WTa | 03/16/95 | 3120 | | | | | | | | 823 | 76.1 | 0.75 | | | 0.160 | 0.0103 |
| WTb | 09/15/94 | 1145 | 8.20 | 20.3 | 2.4 | 220 | 2.1 | 0.10 | 256 | 220 | 19.8 | 0.79 | 23.6 | 0.065 | 0.056 | 0.0037 |
| WTb | 03/16/95 | 985 | | | | | | | | 176 | 19 | 1.45 | | | 0.049 | 0.0023 |
| WTc | 10/13/94 | 1335 | 7.85 | 71.5 | 7.6 | 186 | 4 | 0.3 | 250 | 279 | 29.2 | 0.77 | 21.8 | 0.061 | 0.072 | 0.0027 |
| WTc | 03/17/95 | 1335 | | | | | | | | 276 | 28.5 | 0.79 | | | 0.069 | 0.0020 |
| Permian | 09/15/94 | 97300 | 8.10 | 899 | 417 | 25800 | 49.2 | 17.5 | 140 | 39230 | 3968 | 0.27 | 13.3 | 2.66 | 6.28 | 0.1300 |
| Permian | 11/09/94 | 97500 | | | | | | | | 39640 | 3645 | 0.36 | | | 6.12 | 0.1090 |
| Permian | 05/17/95 | 99100 | | | | | | | | 40110 | 4052 | 0.38 | | | | |
| S. well | 10/13/94 | 2180 | 7.75 | 101 | 14.8 | 324 | 3.4 | 0.69 | 249 | 539 | 55.4 | 2.46 | 22.5 | 0.048 | 0.155 | 0.0048 |
| RSC | 09/15/94 | 10200 | 8.10 | 96.6 | 38.9 | 2080 | 6.5 | 1.56 | 187 | 3175 | 317 | 0.09 | 16.0 | 0.303 | 0.462 | 0.0138 |
| RSC | 10/13/94 | 9030 | | | | | | | | 2736 | 281 | 0.70 | | | 0.44 | 0.0104 |
| RSC | 03/16/95 | 4090 | | | | | | | | 1121 | 147 | 0.41 | | | 0.1543 | 0.0080 |

S. well = South well (well south of Rattlesnake Creek)
RSC = Rattlesnake Creek at the Witt site.
Sp.C. = specific conductance at 25 degrees Celcius.

well WTb next to the Permian well is fresher, as was expected for a greater distance from the creek than WTa. However, water from well WTc is somewhat more saline (chloride content of about 280 mg/L) than that from well WTb even though it is farther from the creek than WTb. The salinity of the water table wells remained relatively steady over the winter compared to that of Rattlesnake Creek even though WTb and WTc were deepened (see Appendix A).

The salinity of Rattlesnake Creek water fluctuates widely depending on variations in streamflow. Specific conductance (SpC) values measured in the field (table 5) ranged from as low as 600 µS/cm during flood conditions in May 1995 to 10,000 µS/cm during low flow in September 1994. The laboratory analysis of a sample collected in September gave a chloride concentration of 3175 mg/L and a SpC of 10,200 µS/cm. The dissolved solids of Rattlesnake Creek as represented by the SpC varies inversely to the streamflow (represented by stream level) with time (figure 6). The effect of even small changes in the stream level can be seen in the SpC variations. The relationship between SpC and stream level is shown in figure 7. The relationship is controlled by the dilution of saline ground-water discharge by freshwater during and following substantial atmospheric precipitation. Note that figure 7 does not show low flow data (and higher SpC values) from 1994 because a stream gage had not yet been installed. However, the hyperbolic shape of the curve in figure 7 indicates that appreciable increases in SpC are expected with small drops in stream level during low flow conditions.

The nitrate concentrations of the ground waters sampled from the monitoring wells and Rattlesnake Creek at the Witt site were all low; all but one value of $NO_3$-N were <1 mg/L. The water from the south well in the site area had a nitrate concentration greater than all the other ground waters sampled, although the value, about 2.5 mg/L, would not be considered high. In comparison, $NO_3$-N concentrations in the upper aquifer at the Siefkes site are as great as 33 mg/L.

The source of the saltwater in the strata in which the Permian well is screened is entirely dissolution of halite or rock salt. No oil brine source of chloride was detected in the two samples for which bromide and chloride were determined. The bromide/chloride mass ratio for the two Permian samples (table 6) is within the same range (0.00006-0.0002) as for natural saltwaters collected from the Permian strata at the monitoring network wells (Whittemore, 1993). The sodium/chloride mass ratio is within analytical error of the 0.649 expected for dissolution of halite. The fact that the sodium/chloride ratio matches the theoretical solution of halite indicates that the salinity of the saltwater in the Permian has been relatively constant for a long time. Deviation from this ratio could suggest historically recent change in the flow of saltwater within the Permian strata.

The salinity source for the shallow monitoring well waters and the sample from the well south of Rattlesnake is also Permian halite dissolution. The bromide/chloride, boron/chloride, and sodium/chloride ratios are all generally consistent with the mixing of freshwaters with higher ratios with the Permian saltwater with lower ratios. The ratios do not suggest an appreciable effect on the shallow water salinity from

Table 5. Specific conductance (SpC) and stream level for Rattlesnake Creek at the Witt Site.

| | Date | SpC (field) (uS/cm) | Stream Level (ft) |
|---|---|---|---|
| RSC | 9/12/94 | 9800 | |
| | 9/14/94 | 9870 | |
| | 9/15/94 | 9980 | |
| | 10/13/94 | 9170 | |
| | 3/9/95 | 6600 | 1836.6 |
| | 3/16/95 | 4080 | 1836.75 |
| | 4/12/95 | 5090 | 1836.65 |
| | 4/13/95 | 5220 | 1836.64 |
| | 4/14/95 | 5360 | 1836.63 |
| | 4/24/95 | 4500 | 1836.74 |
| | 4/25/95 | 4610 | 1836.72 |
| | 4/28/95 | 5050 | 1836.67 |
| | 5/1/95 | 3340 | 1836.98 |
| | 5/2/95 | 3410 | 1836.95 |
| | 5/3/95 | 3640 | 1836.91 |
| | 5/5/95 | 4060 | 1836.84 |
| | 5/15/95 | 600 | 1838.82 |
| | 5/17/95 | 1700 | 1838.08 |
| | 5/18/95 | 1600 | 1837.95 |
| | 5/19/95 | 2010 | 1837.84 |
| | 6/20/95 | 2900 | 1837.02 |
| | 6/21/95 | 2930 | 1836.96 |

RSC = Rattlesnake Creek.

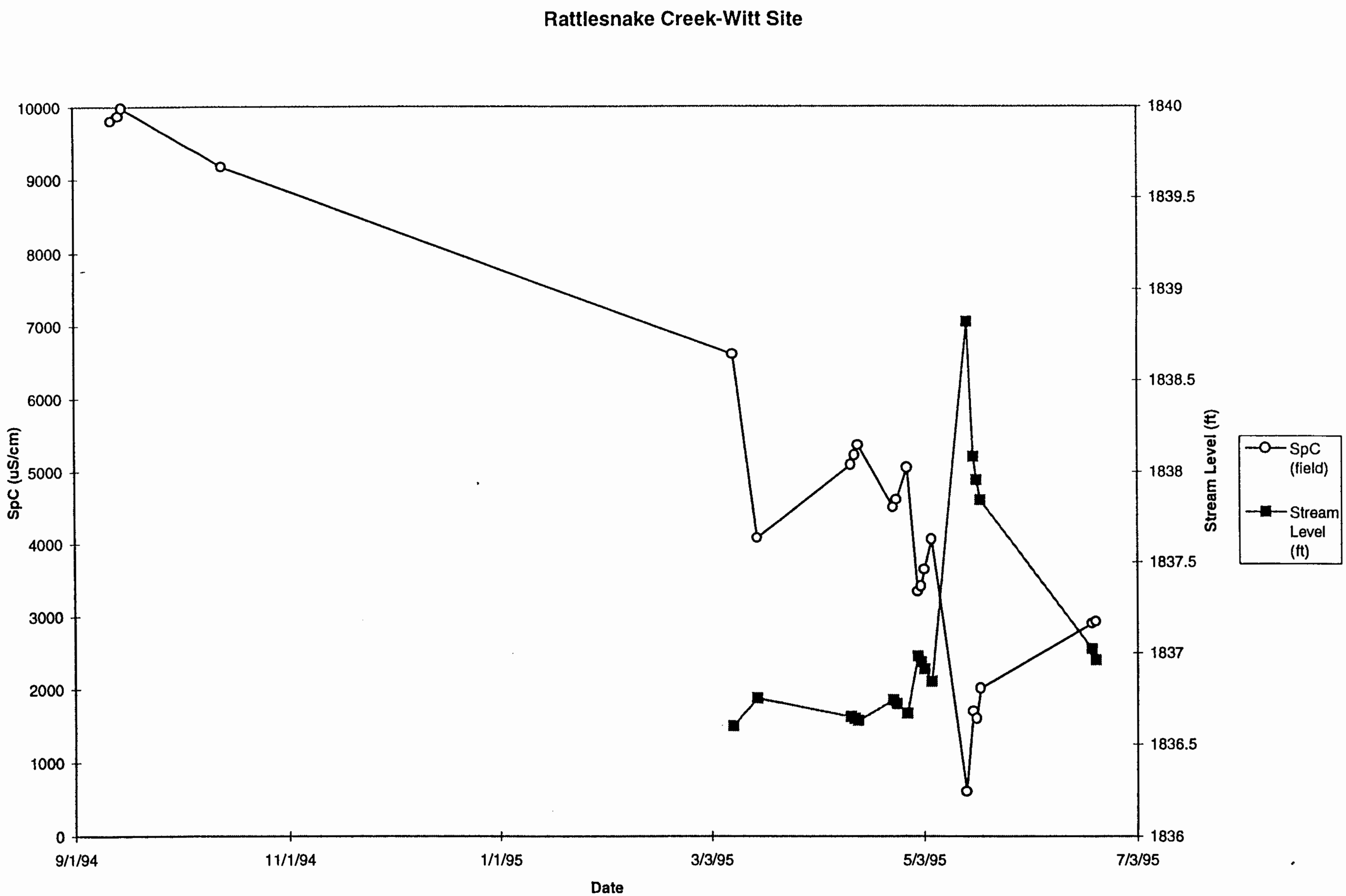


Figure 6. Comparison of stream level and field-measured specific conductance (SpC) of Rattlesnake Creek at the Witt site.

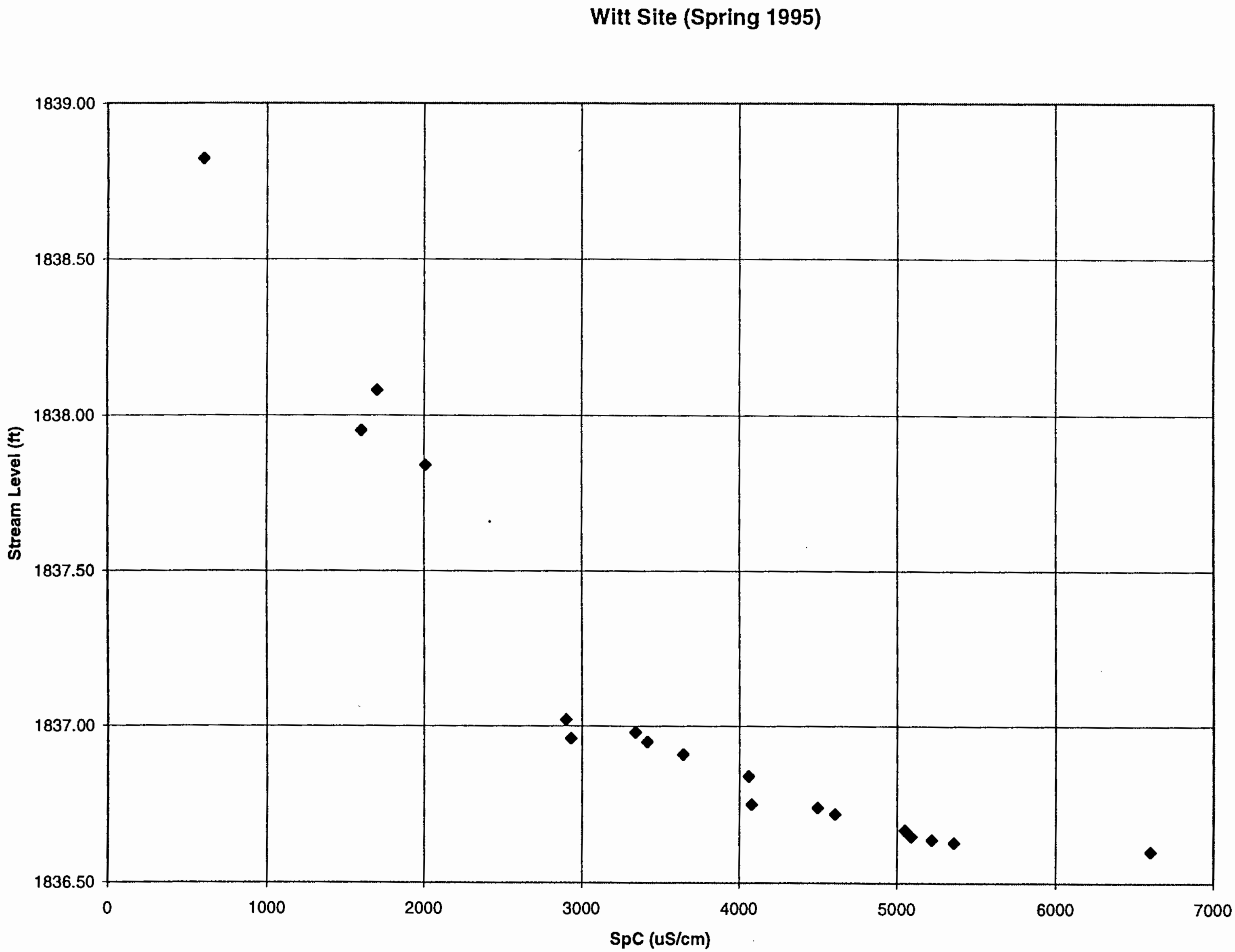


Figure 7. Stream level vs. field-measured specific conductance (SpC) of Rattlesnake Creek at the Witt site.

Table 6. Chloride concentration and constituent mass ratios for well waters and Rattlesnake Creek at the Witt site.

| Sample site | Date collected | Cl mg/L | Na/Cl | $SO_4$/Cl | Br/Cl x $10^4$ | B/Cl x $10^4$ |
|---|---|---|---|---|---|---|
| WTa | 10/12/94 | 749 | 0.782 | 0.0919 | 1.91 | 1.72 |
| WTa | 03/16/95 | 823 | | 0.0925 | 1.94 | |
| WTb | 09/15/94 | 220 | 1.000 | 0.0900 | 2.55 | 2.95 |
| WTb | 03/16/95 | 176 | | 0.1080 | 2.77 | |
| WTc | 10/13/94 | 279 | 0.667 | 0.1047 | 2.58 | 2.19 |
| WTc | 03/17/95 | 276 | | 0.1033 | 2.51 | |
| Permian | 09/15/94 | 39230 | 0.658 | 0.1011 | 1.60 | 0.68 |
| Permian | 11/09/94 | 39640 | | 0.0920 | 1.54 | |
| Permian | 05/17/95 | 40110 | | 0.1010 | | |
| S. well | 10/13/94 | 539 | 0.601 | 0.1028 | 2.88 | 0.89 |
| RSC | 09/15/94 | 3175 | 0.655 | 0.0998 | 1.46 | 0.95 |
| RSC | 10/13/94 | 2736 | | 0.1027 | 1.61 | |
| RSC | 03/16/95 | 1121 | | 0.1311 | 1.38 | |

S. well = south well (well south of Rattlesnake Creek)
RSC = Rattlesnake Creek

evapotranspiration concentration of salts. A greater bromide/chloride ratio would be expected as observed in shallow ground waters below some irrigated fields in the Great Bend Prairie (Whittemore, 1993). The sodium/chloride ratio of the water from the south well is somewhat lower than expected for the chloride concentration suggesting the possibility of historic migration of more saline water to the location.

Transition Zone Characteristics

The freshwater-saltwater interface or transition zone is shallow at this site near Rattlesnake Creek (see conductivity log on figure 4). For comparison, at the Siefkes site, the 500 mg/L chloride elevation (see Garneau et al., 1995) is about 130 ft deep, while at the Witt site is only about 30 ft deep in the vicinity of the Permian well. Only limited logging data have been collected. Figure 8 shows the elevation of the 500 mg/L level compared with water levels at the Witt site. The decline in the 500 mg/L elevation in 1994 is probably related to recovery from drilling. Logging and monitoring of the Witt intensive study site will continue.

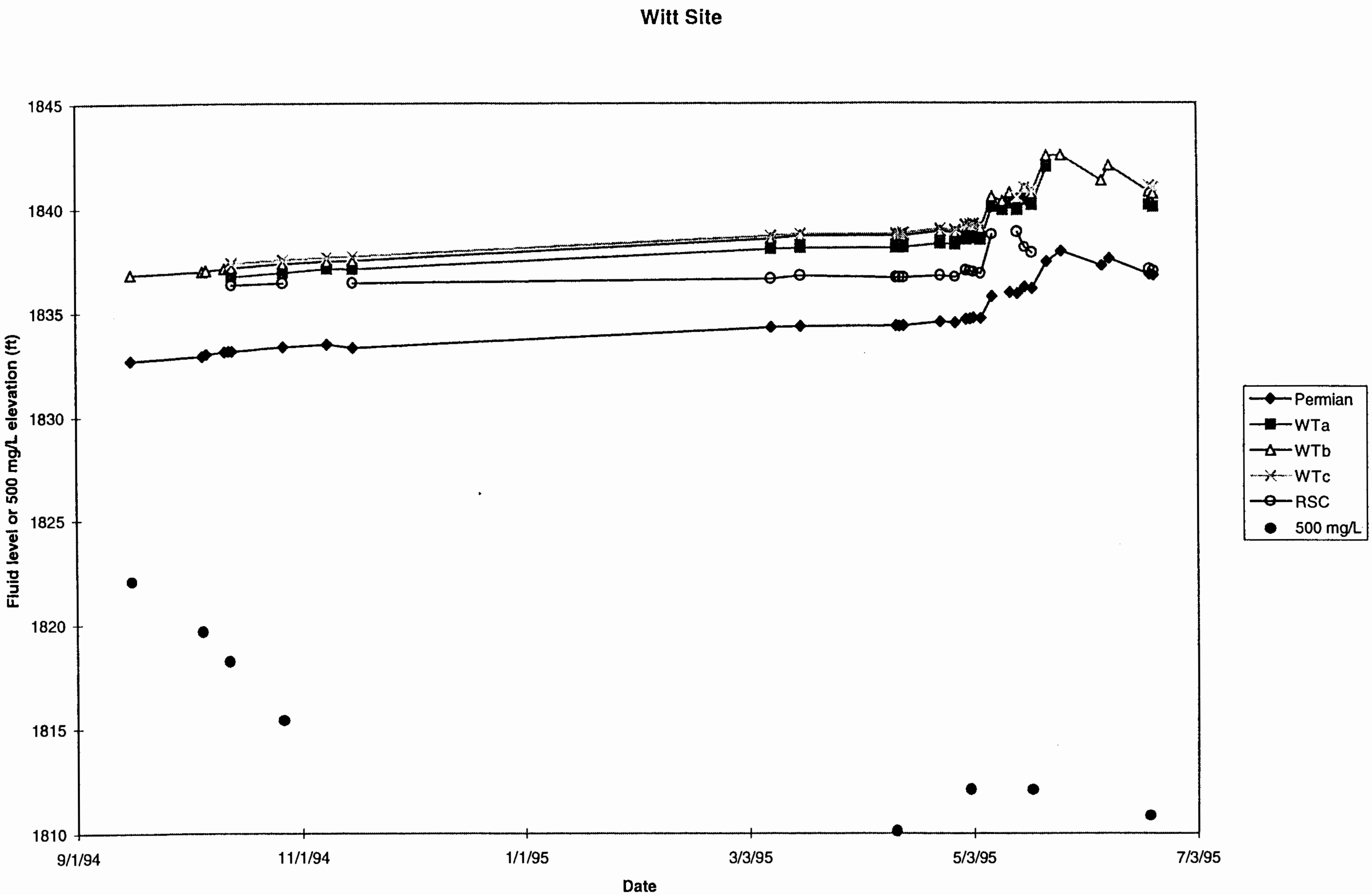


Figure 8. Hydrographs of wells and Rattlesnake Creek (RSC) at the Witt site, shown along with the elevation of the estimated 500 mg/L chloride level in the Permian well (estimated by Garneau et al., 1995). Well descriptions and locations are given in table 1 and figures 2 and 3.

## References

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## Appendix A. Installation and Development of Monitoring Wells and Stream-Level Gage at the Witt Intensive Study Site

The Kansas Geological Survey Exploration Services Section (ESS) drilled the monitoring wells in September and October of 1994. The ESS drill rig is the versatile Acker Soil-Max capable of augering, straight rotary, and coring or any combination of these methods. This report describes the augering of the three shallow wells, the straight rotary and coring of one deep Permian well, the installation of the stream-level gage, and the development of the wells and gage.

### Shallow monitoring wells

Using 6-5/8 inch hollow stem augers, the shallow wells were drilled to depths below the water table until penetrating a saturated sand interval suitable for screening. The three shallow wells were completed by the pull back method in which the large diameter flights are drilled to the bottom of the well and the casing and screen centered within them. Auger cuttings and drilling rate indicated the type of material in the subsurface and determined the depth of the wells. The gross lithology of the material drilled was noted and hand samples placed in sample bags for future study.

Four inch diameter PVC sch. 40 casing was selected to accommodate a 4 inch submersible pump for development and sampling. The well intake consisted of 5 feet of 4 inch 10 slot screen and a bottom cap to keep sediment from entering the well during development, sampling, and other activities. Above the screen, bell joint casing strings were attached and lowered into position through the center of the hollow stem auger. The casings and screens were used to dislodge a plate located in the cutter of the auger flights. If the bottom plate resisted dislodgement, a length of tremie pipe lowered along the side of the casing string was used.

Well WTb borehole annulus was filled with a gravel pack to a level two feet above the top of the screen. The gravel pack was placed by the free fall method. With the gravel in position, the remaining auger flights were removed. The hole experienced collapse of native silt and clay to 15 feet below grade. The borehole was completed with approximately 10 feet of bentonite hole plug to 4.5 feet followed by 3.5 feet of native clay backfill to within a foot of the surface. The remaining borehole was then topped off with Ben-Seal bentonite.

In Wells WTa and WTc, no gravel pack was added to the auger flights. The flights were pulled back approximately 5 feet, the length of the screen. This action exposes the well screen to the formation and also allows formation collapse. A sudden rise in the water level within the casing provides a check of water movement from the formation to the well and borehole. Not until the removal of water from inside the casing produced a favorable water level response were the remaining flights pulled from the borehole. Minor hole collapse was experienced in both wells and the remaining borehole annulus was completed similar to that described for Well WTb.

#### Developing the Shallow Monitoring Wells

After the installations were complete, the screened intervals were developed by pumping, overpumping, and backwashing with a 4 inch submersible pump. Well development is a means of removing fine clay and silt particles from the vicinity of the well screen. Removal of the particulate material decreases the likelihood that water samples will be turbid and increases the communication between the borehole, well intake, and the formation. The pumping, overpumping and backwashing method dislodges and mobilizes the disturbed material surrounding the well intake. Controlled pumping establishes water movement towards the well and transports fine detritus into the well for removal. Pumping at a given rate over a period of time causes bridges to occur within the gravel packs and the formation. Pumping followed by backwashing reverses groundwater flow and breaks the bridges that may develop. Formation water was captured and stored for backwashing purposes in order to minimize any adverse effects associated with introducing water with dissimilar chemistry. After repetitive pumping and backwasing cycles, the wells were overpumped to develop the formation beyond the reaches of the controlled pumping. A return to pumping and backwashing followed by overpumping was repeated until the wells produced less turbid waters.

Turbidity and well performance, each periodically measured, determines the development time frame. An increase in a well's specific capacity indicates an improvement in well performance. Development continues until no more increase is seen. Based on the estimates of specific capacities, the use of gravel packs did not improve well performance; therefore, the low yields are due to low formation permeability and not the well construction. Wells WTa, WTb, and WTc performed as follows: 10 gpm/ ft of drawdown, 1.3 gpm/ 10 ft of drawdown, and 1.4 gpm/ 10 ft of drawdown, respectively.

Modifications to Wells WTb and WTc

It was determined from an elevation survey and well development that water table wells a, b, and c were not within the same stratigraphic position and that, for optimum conditions, intakes on wells b and c needed to be deeper. Redrilling the wells was taken under consideration; however, the cost of abandonment and redrilling far outweighed the alternative method. A driven extension of the wells was deemed to be the most economical means of repositioning the well intakes.

As was mentioned previously, wells b and c were equipped with 4 inch PVC caps on the bottom for well seals. Figure A1 illustrates well conditions prior to modification and the equipment use in the modifications. The extension of the two wells required that the caps be removed or drilled through to allow a smaller diameter casing and screen to be extended to the correct depths. If the caps remained intact, the driving of the extensions would have undoubtedly broken the 4 inch PVC cap and/or casing in an undesirable manner. Using a Giddings soil probe, a 2-1/4 inch hole saw was used to cut through the 4 inch cap. The 2-1/4 inch hole saw was welded to the first 5 foot section of square kelly bar and was lowered to the bottom of the well. This 5 foot section of kelly with the hole saw attached was also equipped with two centralizers, one immediately above the saw and the other at approximately 4. 5 feet above the saw (fig. A1). The centralizers were used to center the hole saw bit and keep it from "walking" around the bottom of the well.

After the hole was cut, the kelly and fashioned hole saw bit was removed and the hole measured. The well extensions were lowered into the well and consisted of 1-1/2 inch diameter by 48 inch length well points and 1-1/2 inch schedule 40 steel pipe of appropriate lengths to extended the wells to the desired depths (see table 1 and figures 3 and A1). The well extensions also were equipped with 1-1/2 inch by 4 inch packers at the top. The packers were used to control the inflow of sediment into the well during development and successive water sampling runs. The well points were driven into position with a hydraulic jack hammer. The points were driven using the square kelly bars with centralizers for aligning the percussion blows and centering the well point. The connection between the kelly bars and the well point extension was equipped with quick disconnect at the packer.

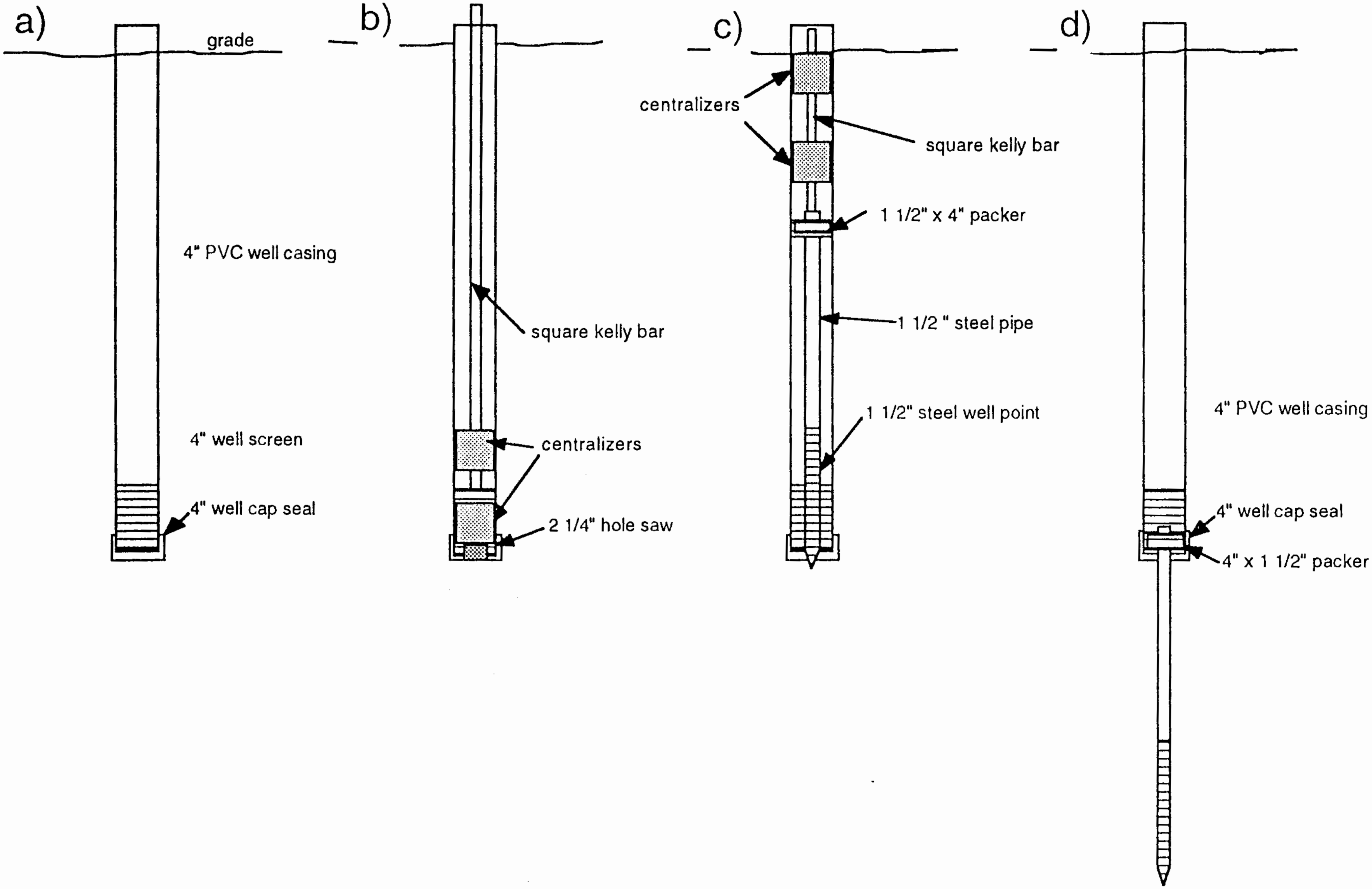


Figure A1. Equipment used in wells WTb and WTc modifications: a) Earlier well conditions prior to modifications, b) lowered saw hole via square kelly bar to the bottom of each well to cut 4" PVC cap, c) installed 1 1/2" extension into the well, and d) driven well point into desired position.

After the well extensions were in place, the top of the packer and total depth were measured to assure the correct position of the well-point intakes and packers. The wells were again developed, however airlifting was the method of choice. The wells showed a marked improvement in drawdown and recovery responses. The modifications still allow water samples to be collected using a 4 inch submersible pump. Drawdown and recovery responses, as well as waters sampled, are now a combined influence of the 4 inch well screen and the 1-1/2 inch well-point intake.

**Permian Monitoring Well**

Since the Permian monitoring well spans the freshwater-saltwater transition zone in the aquifer, extreme care was taken that the borehole did not provide a pathway for artificial upward migration of brine. To facilitate the Permian coring operation, the plan included installation and grouting of 3 inch PVC sch. 40 casing first, and later coring through the bottom of this installation (described below). Prior to drilling, it was determined that grouting through a classic cement shoe would provide the necessary seal within the borehole, enabling collection of Permian core while minimizing the diameter of the borehole.

The KGS designed and fabricated the cement shoe with minor modifications to a classic cement shoe. It was constructed from common PVC materials to facilitate the coring operation following installation and grouting. The construction of the cement shoe consists of a 3 inch PVC coupling, 2 x 3 inch PVC reducer, PVC extension, reinforcing cement , machined inner part (PVC) for strength and ball seat, a spring, five outlet ports for grout and, a buoyant nylon ball (fig. A2).

The following is a summary of drilling and installation procedures used for the Permian monitoring well at the Witt site. Figure A3 schematically illustrates the drilling and installation steps in the procedure, as follows:

A. Site conditions prior to drilling - stratigraphic units and depth to bedrock estimated from available well logs and maps.

B. Using a 4-7/8 inch diameter spade or drag bit and straight mud rotary techniques, the borehole was drilled to a total depth of 159 feet. Drill cuttings were caught with a strainer at the hole discharge, described and bagged. The 159 foot TD is approximately 12 feet into the Permian red beds. The upper part of the Permian is of interest; however, it was drilled to guarantee a good grout seal through the upper part of the Permian and at the alluvial-bedrock interface (147 feet).

C. After the drill hole is flushed and cleaned by circulation, the drilling fluid viscosity is reduced. The 3 inch bell joint PVC casing with the 3 inch cement shoe on the bottom is lowered into the borehole. Although the drill fluid has been thinned, fluid must be added to the inside of the casing to cancel buoyancy effects. The illustration shows the 1-1/4 inch tremie pipe being lowered inside the well casing. The tremie pipe has a machined brass end with o-rings that seals into the top of the cement shoe (fig. A3). In the past the KGS has used cement shoes that join to the tremie pipe with a 1 inch left hand NPT. In that situation, the well casing and tremie must be set at the same time. With the brass fitting on the first joint of tremie, the casing can be set and then the tremie can be lowered until the brass adapter slides into the shoe. The o-rings on the adapter seal the connection between the tremie pipe and the cement shoe.

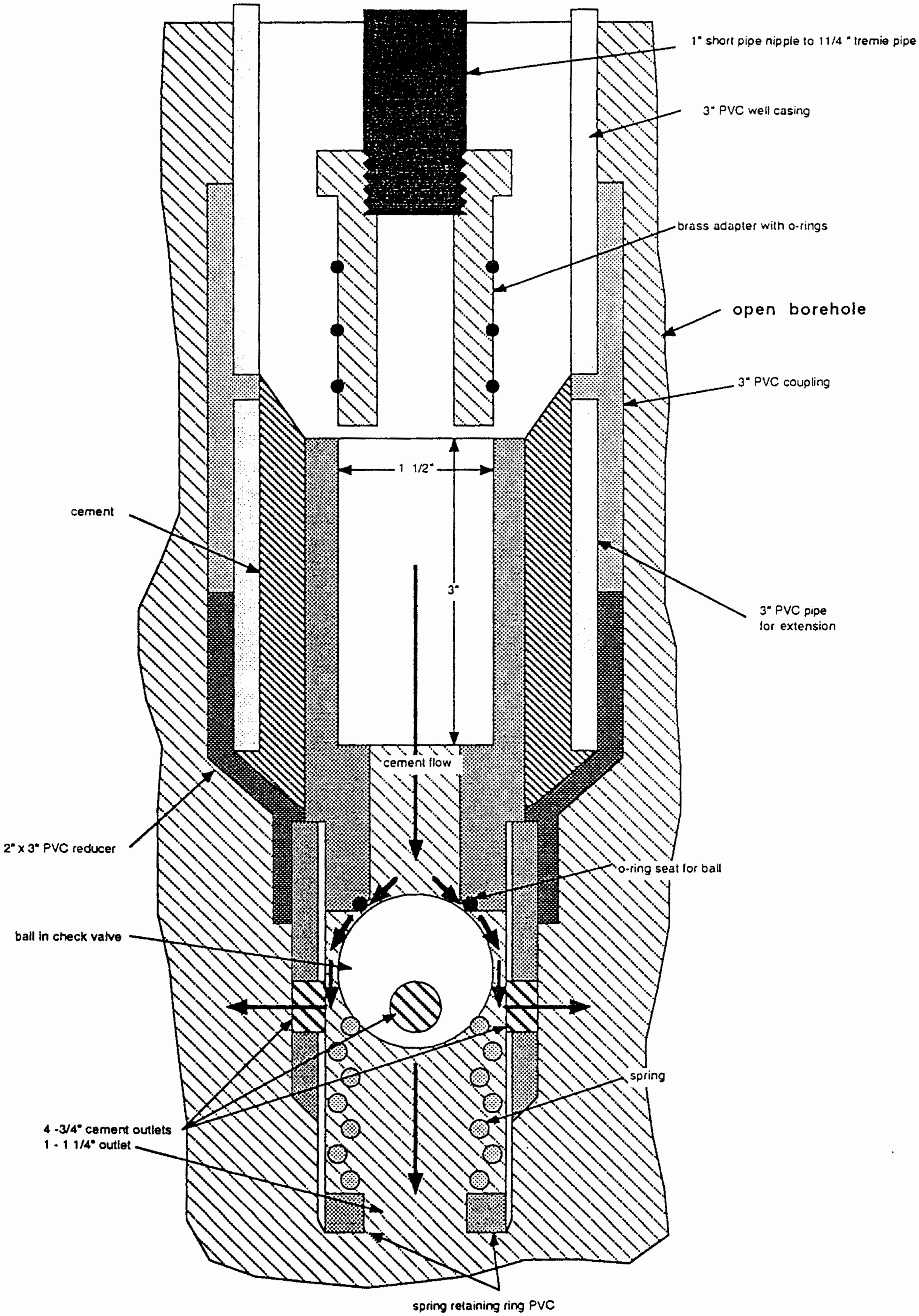


Figure A2. Schematic of cement shoe and tremie pipe brass adapter

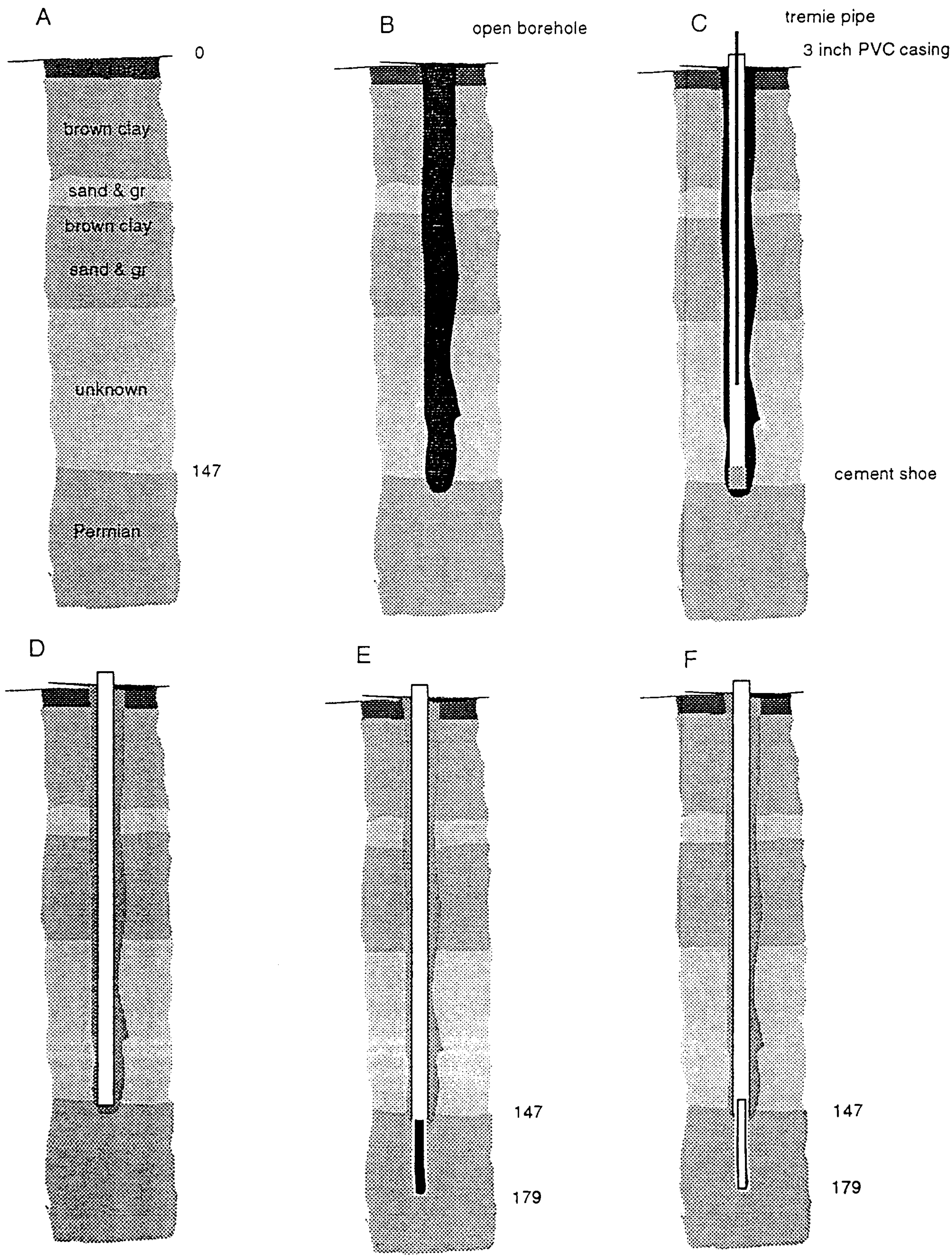


Figure A3. Sequence of Permian montoring well installation operations

D. Cement grout is pumped down through the tremie pipe and cement shoe and up the annular space to near land surface. The casing string must be held in place off the bottom of the borehole. The tremie must also be held so the connection between the two remains intact. The volume of cement used at the Witt site is: the volume of the borehole to the surface minus the 3 inch PVC casing plus 15%. The additional 15% volume of cement is used to fill in the washout areas and any invasion into porous substrata. The grout consists of 5-6 gallons of water to 90 lbs. of portland Type I cement. This assures a reliable seal in a saline environment, which is of utmost importance. After the cement becomes visible at the surface, the equipment is flushed with fresh water. When tremie pipe is removed, the fluid level in the casing must remain relatively constant. A sudden rise in the fluid means the cement shoe failed to seat and must be jarred into place. Once conditions have stabilized the cement is allowed to cure.

E. After the cement has cured, the cement shoe and bottom plug are cored. An additional 20 feet (159-179 feet) of the Permian formation is cored below the bottom of the original hole. The core is described and boxed according to standard field practices. The upper part of the core contains the ball, spring, and o-rings of the cement shoe, assuring successful grouting. After the coring was complete, the drill string was removed.

F. Installation of 2 inch PVC screen and casing is placed into the open core hole. Twenty feet of 2 inch sch. 40 screen will control hole collapse while giving the well structural integrity for future geophysical logging and other well activities. The 10 slot screen will contain the silts and clays of the Permian formation and allow formation waters to flow unimpeded into the well for sampling and water level acquisitions. The 10 foot of 2 inch PVC above the screen protrudes up inside the 3 inch casing. The top of the 2 inch casing was measured to ensure installation to the bottom of the core hole.

Following installation, the borehole grout was sounded at 21 feet. Cement grout was added to the borehole through tremie pipe to a depth of 8 feet. The upper 8 feet was sealed with bentonite Ben-Seal to grade.

Developing the Permian well

The well was developed by the airlift method in which an airline is lowered into the well to near the bottom. Using an air compressor, saline water was discharged at a rate of 5 to 6 gpm. The development process is an attempt to remove drill fluid effects in the vicinity of the well. When coring with fresh water (as opposed to drilling mud), a filter cake does not develop in the core hole wall. Since fresh water was used during the coring operations, the time required for development was minimal. Approximately 300 gallons of saline water were airlifted and captured for disposal. In a short time period (1 hr), the water had become visibly less turbid. The airline was removed and the total depth measured for sediment fill. Hole loss was experienced. An eductor pipe and airline were lowered to the sediments in the hole and the sediments were airlifted out. The results of this final clean-out phase left the well in satifactory condition with a total depth the same as pre-development (179 ft TD).

## Stream Level Gage

A stilling well was installed along the Rattlesnake Creek to record the fluctuations in the stream level. The simple construction of the well consist of vertical 4 inch PVC casing approximately 5 foot in length with a 4 inch by 2 inch PVC tee installed within a foot of the bottom. Glued to the 4 inch by 2 inch tee was a horizontal length of 2 inch screen and casing to allow an inlet from the stream to the well casing (fig. A4). The casing and stream inlet were installed in a hand dug trench and augered borehole. The trench was backfilled

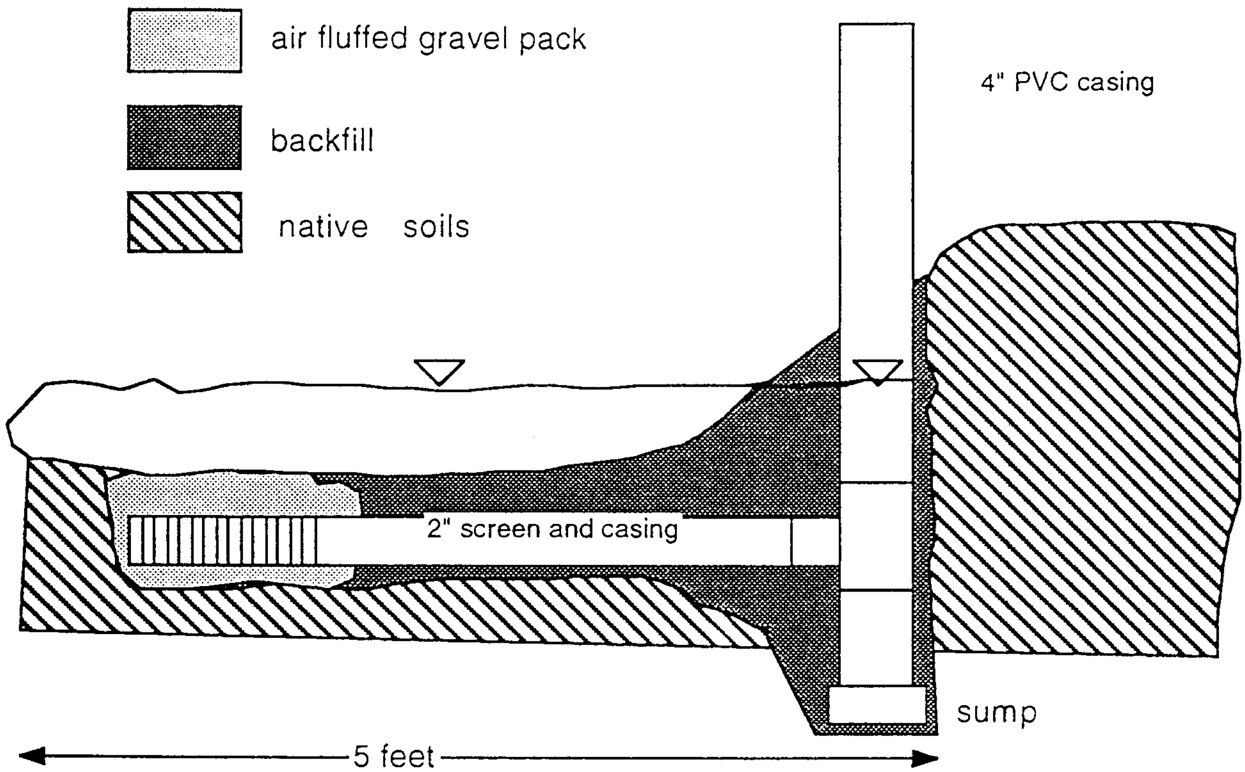


Figure A4. Four inch stream level gaging station along the Rattlesnake Creek.

and a layer of coarse gravel was laid upon the 2 inch stream inlet to reduce silting of the screen. The gravel overlay was repeatedly cleared of fine detritus by injecting air into the 4 inch well casing. This action provided a graded gravel pack adequate for filtration of stream sediment.

Following installation and development, all wells and Rattlesnake Creek were sampled for water chemistry. The monitoring wells were logged and surveyed. Permian cores were analyzed for permeability and porosity; these results will be reported later. Stevens Type F water level recorders were installed on the Permian well, wells WTa and WTb, and the stream gage.